# Representation of the Sierra Barrier Jet in 11 years of a high-resolution dynamical reanalysis downscaling

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**Motivation**: The Sierra Barrier Jet (SBJ) is an orographically generated low level jet that often occurs as extratropical cyclones make landfall on the US west coast. These same cyclones often generate the majority of California's precipitation. The SBJ's prevalence during stormy conditions, its influence on moisture advection, and its potential to act as a virtual barrier, lead to the SBJ strongly influencing precipitation distribution. The strong topographically enhanced flow during SBJ conditions also potentially impacts aerosol transport. Because of these important impacts, the SBJ's representation in reanalysis products is critical, but has been previously undocumented. This study documents the SBJ's representation in two reanalysis datasets and two reanalysis downscalings compared with wind profiler observations.

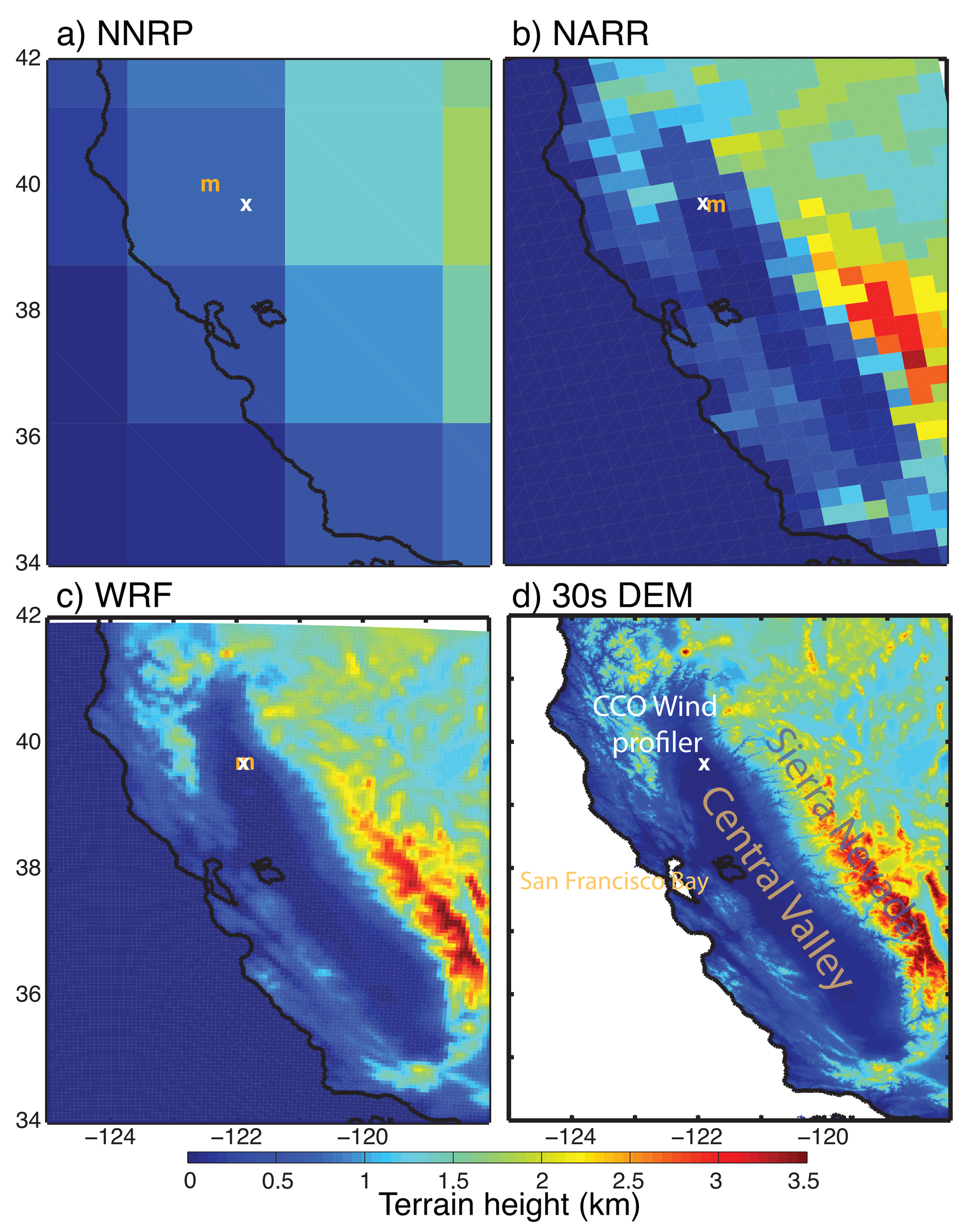


Figure 1: Elevation map of California as represented by (a) NNRP, (b) NARR, (c) WRF-RD, and (d) USGS 30-sec digital elevation map. White 'x' shows location of the 915 MHz wind profiler at Chico.

| Dataset | Horizontal Grid spacing | Number of SBJ Cases | Vmax altitude (m, MSL) | Vmax amplitude (m $s^{-1}$) |
|---|---|---|---|---|
| Wind prof. | N/A | 256 | 800 | 15.39 |
| WRF-RD | 6 km | 204 | 900 | 14.63 |
| CaRD10 | 10 km | 141* | 1450 | 16.73 |
| NARR | 32 km | 159 | 1450 | 16.62 |
| NNRP | 2.5 degrees | 9 | 1550 | 16.51 |

Table 1: A summary of SBJ statistics at CCO from observations and model datasets. *CaRD10 only spans 2001-2008

## Sierra Barrier Jet at Chico, CA

We first inspect the representation of the Sierra Barrier Jet in:

1) NCEP/NCAR Reanalysis Product (NNRP)
2) North American Regional Reanalysis (NARR)
3) California Reanalysis Downscaling to 10 km(CaRD10)
4) Weather Research and Forecasting Reanalysis Downscaling to 6 km (WRF-RD)

The closest gridpoint of each reanalysis or downscaling product at Chico, CA (CCO) is compared with the observed winds from 11 years of 915 MHz wind profiler data. SBJ events were tagged in each dataset by an objective algorithm described in Neiman et al (2010). Resultant composite SBJ along-Sierra wind speed is shown in Fig. 2; WRF-RD's composite profile is the closest to that observed.

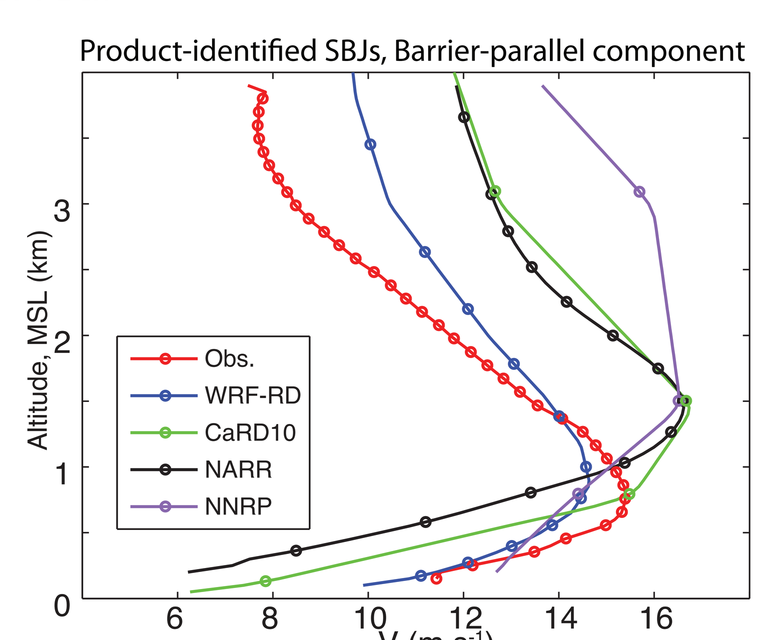


Figure 2 (right): Terrain parallel composite wind speed versus altitude at CCO (or gridpoint closest to CCO) in observations, WRF-RD, CaRD10, NARR, and NNRP.

## SBJs in WRF-RD and NARR

WRF-RD's SBJ is more realistic than NARR's at CCO, but how do the two datasets' winds compare over a larger area during SBJ conditions? At 1000m MSL (Fig. 3), both datasets have southwesterly winds offshore that turn southeasterly within the Central Valley, reaching their maximum of nearly 20 m $s^{-1}$ north of CCO. The winds offshore are 30-40% stronger in WRF-RD, however, and there are large gridpoint-to-gridpoint discontinuities in NARR. Examining the vertical cross sections (Fig. 4), we see that the SBJ in both datasets is roughly 'terrain following', but NARR's representation of terrain is the likely reason for the too-elevated SBJ Vmax of Fig. 2, and causes unrealistic undulations of barrier-parallel wind along the Central Valley.

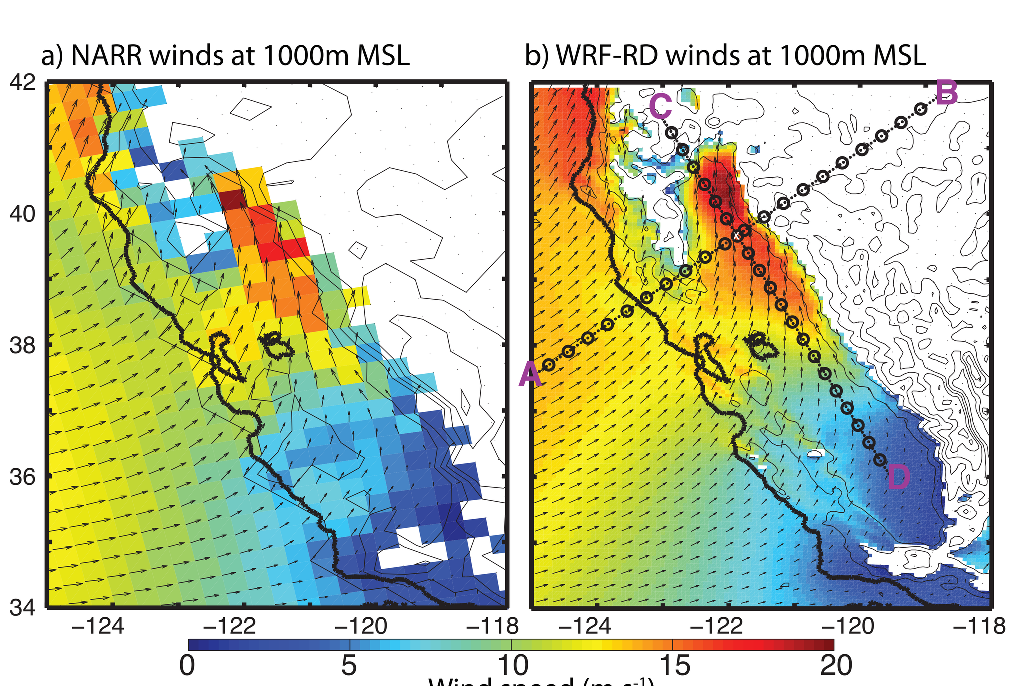


Figure 3 (above left): Composite winds for overlapping SBJ events in (a) NARR, and (b) WRF-RD, at 1000m MSL. Lines AB and CD in (b) show location of cross sections shown in Fig. 4.

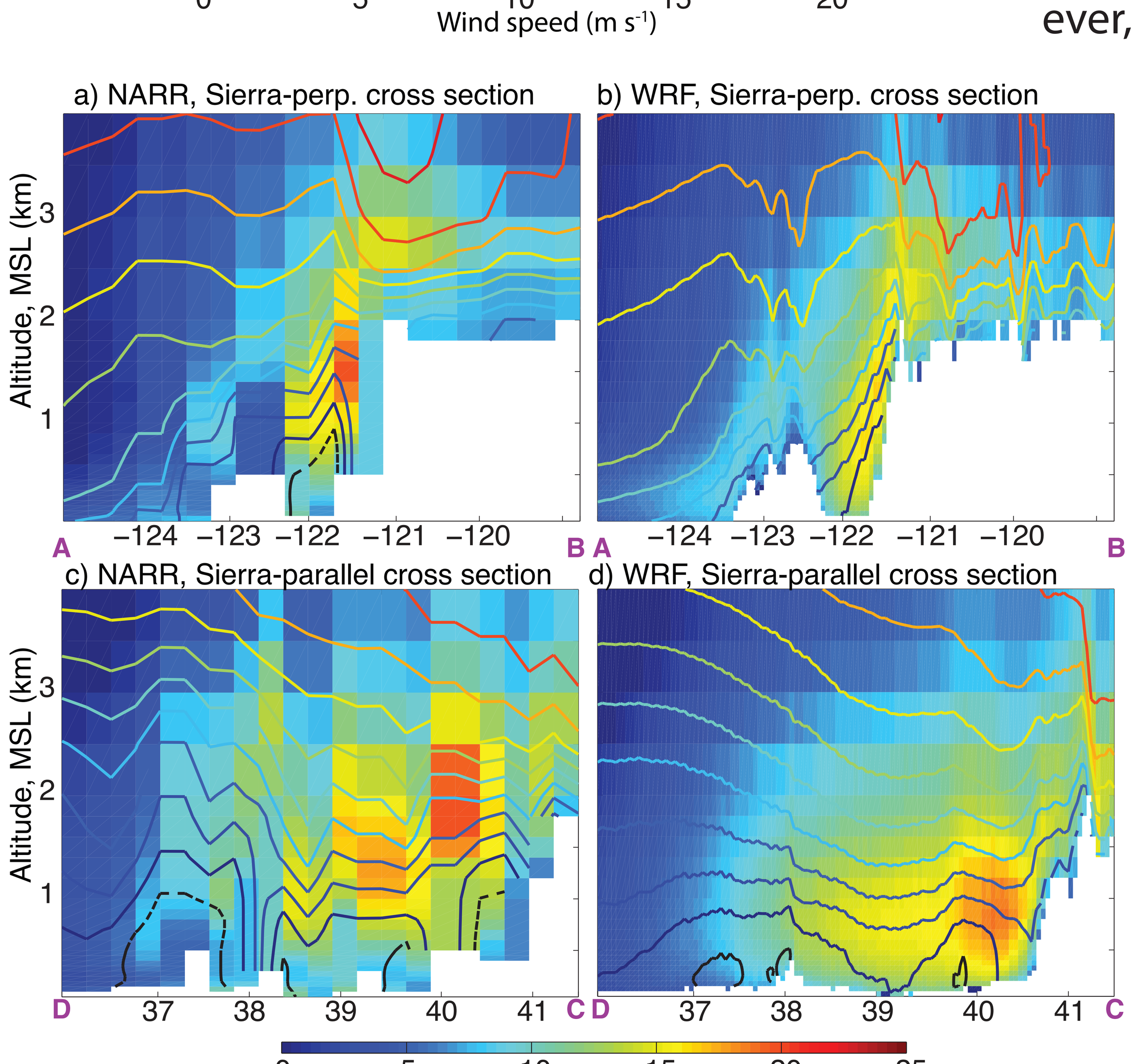


Figure 4 (left): Composite Sierra-perpendicular (line-contours) and Sierra-parallel (filled contours) wind speed for overlapping SBJ events across cross sections of Fig. 3.

## SBJ: Impact on water vapor transport

What do the large differences between WRF-RD's and NARR's winds mean for water vapor transport, a variable to first order directly proportional to orographic precipitation amount? Looking first at integrated water vapor transport (IVT; Fig. 5), we see that both WRF-RD and NARR have strong southwesterly IVT that penetrates through the gap in coastal topography into the northern Central Valley, turning northward as it approaches the Sierra Nevada. WRF-RD's IVT is nearly 50% larger offshore, likely due to the larger wind speeds we saw at 1000m MSL (Fig. 3).

Vertical cross sections of water vapor flux (Fig. 6) are qualitatively similar the corresponding cross sections of wind. However, because water vapor mixing ratios are largest near the surface while across-barrier winds peak aloft, across-barrier fluxes peak ~700m above the surface over the ocean and east of the Sierra crest, but above the SBJ core winds over the Central Valley, suggesting the SBJ acts as a 'virtual barrier'. As with winds, NARR shows large gridpoint-to-gridpoint discontinuities and a complete lack of coastal jet.

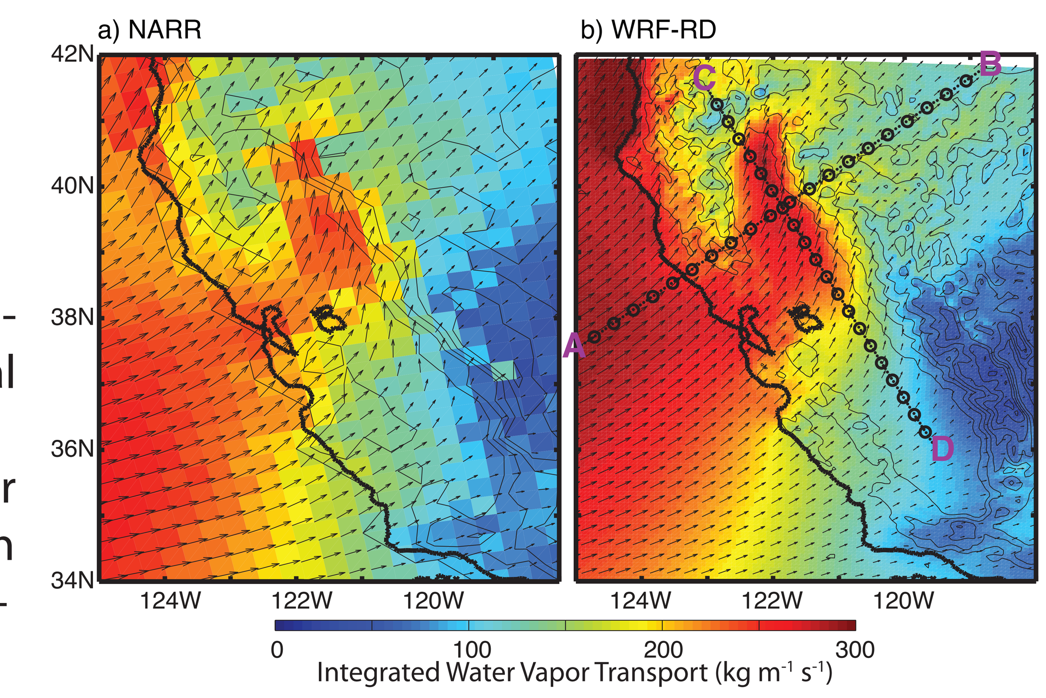


Figure 5 (above right): Composite integrated water vapor transport for overlapping SBJ events in (a) NARR, and (b) WRF-RD, at 1000m MSL. Lines AB and CD in (b) show location of cross sections shown in Fig. 4.

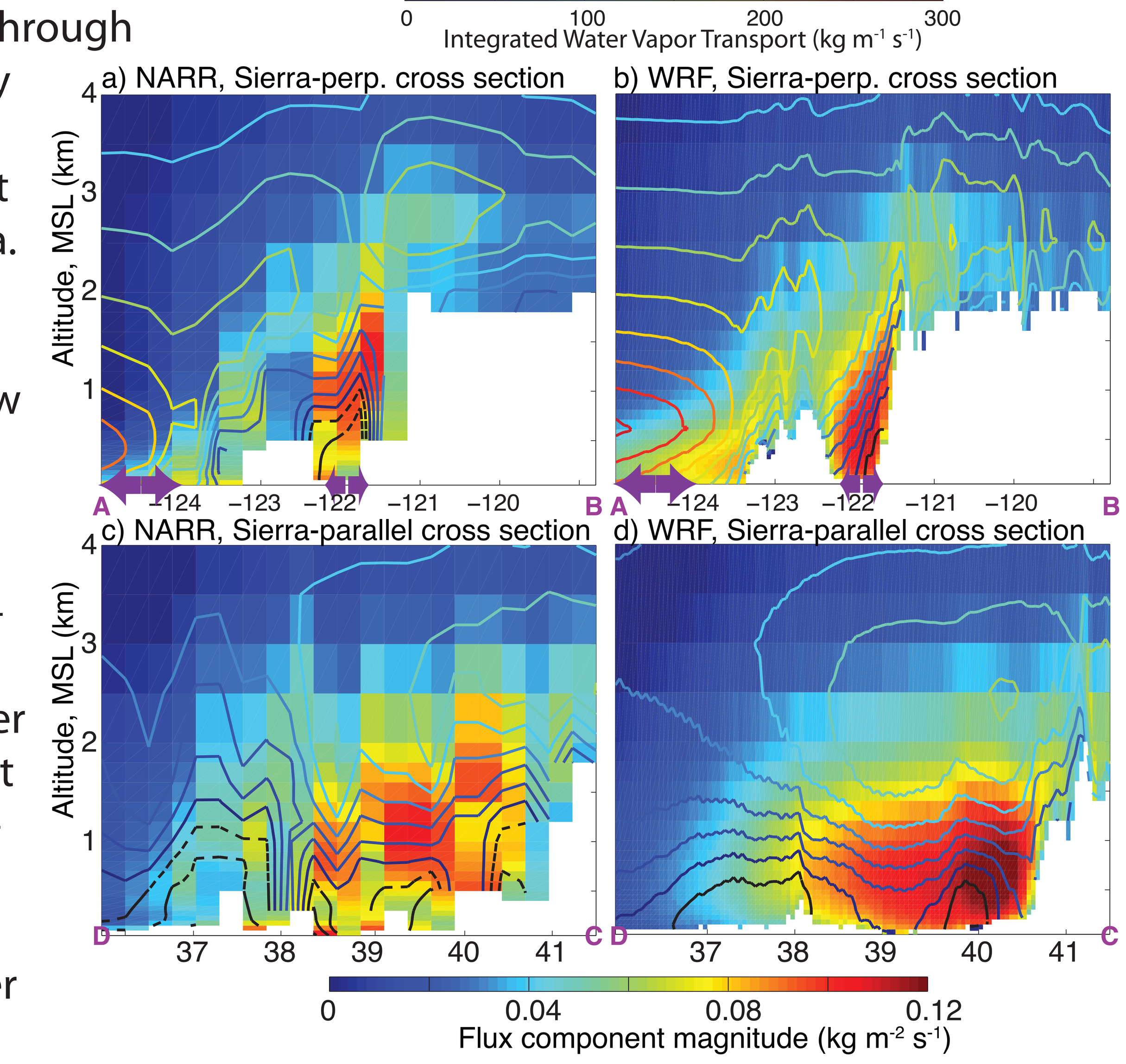


Figure 6 (right): Composite Sierra-perpendicular (line-contours) and Sierra-parallel (filled contours) water vapor transport for overlapping SBJ events across cross sections of Fig. 3. Purple arrows show horizontal integration areas of Fig. 7.

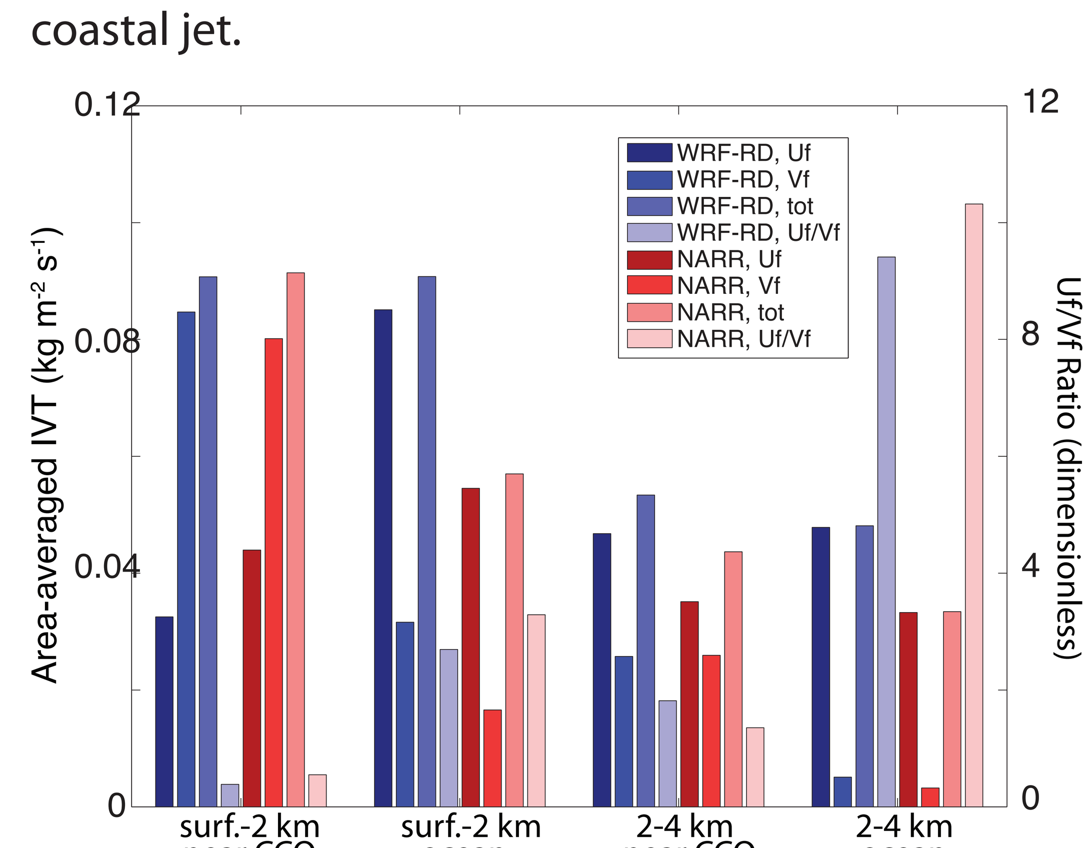


Figure 7: Composite area-averaged integrated water vapor transport during SBJ conditions in (blues) WRF-RD and (reds) NARR.

To summarize how differences in water vapor flux at each gridpoint impact total water vapor transport through the region, we calculate area averaged water vapor transport over two subsections of the across-barrier cross section (Fig. 6 a and b): near CCO (right arrows in each panel) and over the ocean (left arrows in each panel). Gridpoint values of water vapor flux (Fig. 6) are integrated through two depths of atmosphere, integrated horizontally across the regions, then area-averaged to account for the differences in terrain between NARR and WRF-RD. The resultant barrier-perpendicular (Uf), barrier-parallel (Vf), and total (tot) fluxes are shown in Fig. 7, along with the Uf/Vf ratio. In both datasets, only below 2km near CCO is Vf larger than Uf: Water vapor flux transport is dominantly across-barrier outside the SBJ. However, this topographical water vapor flux diversion is more pronounced and more vertically confined in WRF-RD than NARR.

## Conclusions

Of the four reanalysis and reanalysis downscaling datasets examined here, only WRF-RD, at 6 km gridspacing, is able to adequately resolve and represent the SBJ and its associated water vapor transport. This result is important to consider for studies of precipitation processes, and the water vapor transport results also have important implications for aerosol transport in the region.

**References:**

Neiman, P, Sukovich, E, Hughes, M, and FM Ralph (2010) A Seven-Year Wind Profiler-Based Climatology of the Windward Barrier Jet along California's Northern Sierra Nevada, *Monthly Weather Review, 138(4)*, 1206-1233.

Hughes, M, Neiman, P, Sukovich, E, and FM Ralph (2012) Representation of the Sierra Barrier Jet in 11 years of a high-resolution dynamical reanalysis downscaling compared with long-term wind profiler observations, *submitted to JGR-Atmospheres.*

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